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Some Population Parameters of *Cyprinus carpio* (L., 1758) From Yeşilırmak (Samsun, Türkiye)

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ABSTRACT

Current study was carried out between March 2019 and February 2020 to determine the biological characteristics of *Cyprinus carpio*, which is brought to fish markets of Alaca (Çorum) from Hasan Uğurlu Dam Reservoir (Samsun). Total, fork, standard lengths, and weights of 406 individuals were measured and recorded. Sex ratio was calculated as 1:2.1 (♀:♂). Ages were determined by using lateral scales and thus age groups were formed. According to the data collected, equation of length-weight relationship was $W = 0.0163 \times TL^{2.935}$ and an isometric growth pattern was observed for combined individuals. VI age group has the most individuals (n=148). Fulton's condition factor (K) and phi-prime growth index (Φ') were calculated as 1.3 and 2.42, respectively. This study makes a contribution to common carp stock related studies for further common carp fishery management.

INTRODUCTION

The Cyprinidae family is the largest of all freshwater fish families and comprises of about 367 genera and about 3006 species (Nelson, 2016). As a member of this family, *Cyprinus carpio* (Linnaeus, 1758) has a wide distribution area consisting of freshwater ecosystems, especially rivers and lakes (Zencir Tanır, 2020). Due to being one of the most dispersed freshwater fish, *C. carpio* is an ecologically harmful and invasive species (Kulhanek et al., 2011; Vilizzi, 2018; Das et al., 2019) and is listed among the 100 most harmful alien species of the world (Lowe et al., 2000). Being durable, adapting to changing climatic conditions (Crespi & New, 2009), tolerance to temperature fluctuations (Syed et al., 2020) and being able to tolerate changes oxygen levels in water (Rashid et al., 2018). In addition, its rapid growth, rapid reach to sexual maturity, and high fecundity lead to a high invasion potential (Winker et al., 2011; Troca & Vieira, 2012; Vilizzi & Copp, 2017). Common carps have omnivorous (Khan et al., 2020) and opportunistic feeding behaviour (Feher et al., 2021).

In the inland waters of Türkiye, especially gillnets are used for carp fishing and carp fishing has been taken under control with the "Communiqué on the

Regulation of Commercial Fisheries Fishing" (Anonymous, 2020). While the catch amount of carp was ≈10.000 tons in 2011, it decreased to ≈3.000 tons by 2020 (TUIK, 2021). Stock estimation studies related to carp have been made in different water bodies throughout Türkiye (Vilizzi et al., 2014a), and the making of fishery regulations depends entirely on obtaining biological data.

To have information about the biological characteristics of populations, species-specific length-weight relationships and condition factors, are essential for fish biology and population dynamics studies in terms of; i) weight estimation using the length or length classes of the samples; ii) evaluation of available biomass if the length frequency is known; iii) calculation of relative condition value and relative weight; iv) calculate weight at a given age by converting growth in length to growth in weight in stock assessment models; v) comparison of life history parameters and sizes of populations from different locations (Anderson & Gutreuter, 1983; Froese, 2006).

On the other hand, sampling is done by various methods and one of them is market sampling. The market sampling provides an access to some population related parameters such as length-weight relations, age and growth parameters etc. The market sampling is relatively important and has been used for many fishery related studies (Daan, 1974; Bromley, 2003; van Keeken et al., 2004; Spaet & Berumen, 2015; Eltholth et al., 2018). According to our observations market sampling, if the source is well-known, the accurate estimations could be done properly.

Considering the important roles played by *C. carpio* in Turkish inland waters, the determination of the biological characteristics of common carp samples offered for sale in fish markets can be a guide in evaluating their compliance with fisheries regulations. Because, while offering both local fish fauna and carp stocks for human use, it is important to protect the species and use of fish stocks within the framework of the concept of sustainability (Vilizzi et al., 2014a).

This study aims to determine some biological characteristics of *C. carpio*, which was taken from Yeşilırmak (Çarşamba, Samsun) and sold in Alaca (Çorum) fish market. When evaluated in terms of pressures on fisheries and the climate crisis, the data obtained will provide scientific advice in fisheries management, species management, conservation, aquaculture and population comparison. It is also expected to contribute a comprehensive view to develop an effective local fisheries management.

MATERIAL AND METHODS

Study Area

Sampling was carried out between March 2019 and February 2020 to determine the biological characteristics of *C. carpio*, which is brought to fish markets of Alaca, Çorum. The common carp individuals were caught from Hasan Uğurlu Dam Reservoir is located on Yeşilırmak River (Samsun) (Figure 1). Reservoir area is ~ 13,1 km² (Enerji Atlası, 2022). The reservoir is rented to fishermen by state for fishery. Common carps are caught by trammel nets with mesh sizes vary between 70 and 120 mm from the reservoir. Location of the fish samples was corrected by fishermen and fish market owner.

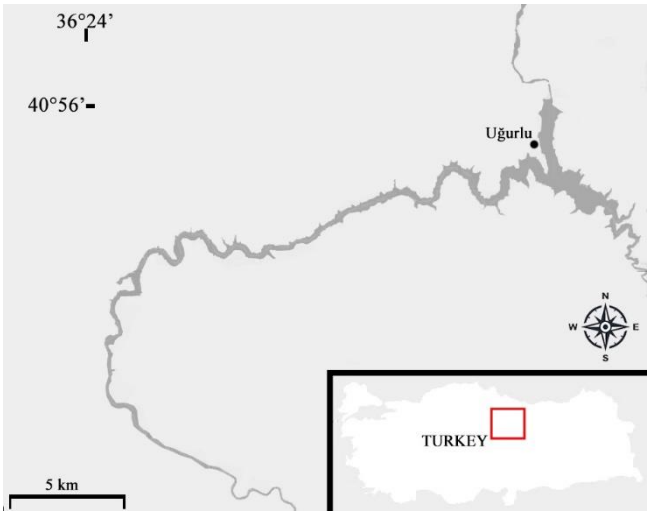

Figure 1. Hasan Uğurlu Reservoir: Origin of the *Cyprinus carpio* samples

Sampling

Within the scope of the study, common carp individuals were obtained monthly from a fish market in Alaca. Fish samples were randomly selected, were iced and were brought to the laboratory where measurements would be made.

Laboratory Examinations

Total length (TL), fork length (FL) and standard length (SL) of the samples were measured (±0.1 mm). Total weights were determined with precision balance (±0.01g).

Length-Weight and Length-Length Relationships

The length-weight relationship was calculated by Equation (Eq.) (1) (Ricker, 1973);

$$W = a \times TL^b \quad (1)$$

In the formula where *TL* is total length and *W* is total weight of fish. Logarithmic transformation was applied to both weight and length parameters to make linear regression analysis. Thus, *a* and *b* values of the length-weight relationship were estimated by Eq. (2);

$$\log(W) = \log(a) + b\log(TL) \quad (2)$$

a and *b*, the coefficient of determination r^2 were also estimated (0.95 CI). Length-weight relationships were determined separately for female, male and all individuals. A "*b*" value of 3 means isometry, < 3 means negative allometry, and > 3 means positive allometry. Whether the "*b*" values obtained were suitable for isometry (*b* = 3) was evaluated with the "*t* test".

Total, fork and standard lengths were used in determinations of length-length relationships. Transformation of all lengths with each other were presented. The length-length relationship with total length among other body lengths with a simple linear regression model by Eq. (3);

$$Y = a + bX \quad (3)$$

where *Y* is various body lengths, *X* is total length, *a* is proportionality constant and *b* is regression coefficient (Alam et al., 2012).

Fulton's Condition Factor

Fulton's condition factor (K) was calculated in Eq. (4) (Froese, 2006);

$$K = \left(\frac{W}{TL^3}\right) \times 100 \quad (4)$$

In the formula where *K* is condition value, *W* is total weight and *TL* is total length of fish.

Growth

Von Bertalanffy's (1957) equation was used to calculate the growth in length (Eq. (5));

$$L_t = L_\infty[(1 - exp^{-k(t-t_0)})] \quad (5)$$

In the formula, L_t is the predicted fish length at age *t*, L_∞ is the asymptotic length, *k* is growth coefficient and t_0 is age of fish at zero length.

Growth performance index (phi-prime)

The phi-prime was calculated to compare the growth parameters in the current study with those of other studies (Munro & Pauly, 1983) (Eq. (6)).

$$\Phi' = \log k + 2\,\mathrm{Log}L_\infty \quad (6)$$

In the formula, Φ' is growth performance index, *k* is growth coefficient ($year^{-1}$) and L_∞ is asymptotic length.

Age Determination

For age determinations, scales between the dorsal spines and the linea lateral were used (Chugunova, 1963). The scales of each fish were taken into separate zip lock bags and tagged. The scales were washed before being taken into zip lock bags, and the mucus and epidermis layer on them were cleaned with the help of a brush. In order to avoid difficulties in the reading process and to avoid mistakes, the scales were kept in 5% NaOH for 2 hours before they were read and washed in 96% alcohol for a while to remove any residues that may be on them (Bolat & Yağcı, 2018). The scales were then examined under a light microscope. Ages were read by three independent readers.

Mean lengths (LaA) of previous ages were evaluated by using the Fraser–Lee back-calculation method (Francis, 1990) (Eq. (7));

$$L_t = c + (TL_c - c)(S_t/R) \quad (7)$$

where L_t is the total length when annulus t was formed, TL_c is total length at capture, S_t is the distance from scale focus to the annulus t, *R* is the scale radius, and *c* is the intercept on the length axis from the linear

relationship of total length versus scale radius (the Fraser-Lee correction factor) (Heidarsson et al., 2006; Top et al., 2018).

Sex Determination

All individuals were dissected to determine the genders than male and female individuals were determined by macroscopic examination.

Data Analysis

All data were evaluated in MS Excel (Microsoft Corporation, 2018) and Statistica (StatSoft, 2012) software. The chi-square (χ^2) test was used to determine the differences in sex ratios. The differences between the total length and weight values of female and male individuals were determined by two-sample independent *t*-test. The Kruskal-Wallis test was used to determine the change in K value according to gender and months. All tests were performed at p = 0.05.

RESULTS

Length-Weight and Length-Length Relations

Totally, 406 individuals were examined in the current study. Among these individuals, 130 were female and 272 were male. The sex of 4 individuals could not be determined. The sex ratio was found as 1:2.1, female to male, and a statistically significant difference was observed in sex ratio ($p < 0.05$).

The total length frequency distribution indicated a dominance of fish between 29.0 and 30.0 cm TL (Figure 2). Total lengths and weights were ranged between 24.9-46.5 cm and 226.7-1369.5 g, respectively. Mean total length and total weight were estimated as 32.88 ± 3.77 cm and 479.46 ± 177.56 g, respectively. The mean total length of females (33.59 ± 3.63 cm TL) was significantly larger than the males (32.57 ± 3.80 cm TL) ($p < 0.05$). The mean weight of females (514.52 ± 181.77 g) also was significantly greater than those of the males (464.8 ± 173.56 g) ($p = 0.008$). The highest (40.8 cm) and lowest (29.9 cm) mean lengths were recorded in October and August, respectively, and the highest mean weight (845.9 g) was observed during October, while the lowest value (337.9 g) was observed in August. The length-weight relationships showed isometric growth for female, male and all (Table 1).

The relationships between TL, FL and SL of the *Cyprinus carpio* including 406 specimens along with the estimated parameters of the length-length relationship and the coefficient of determination R^2 are presented in Table 2.

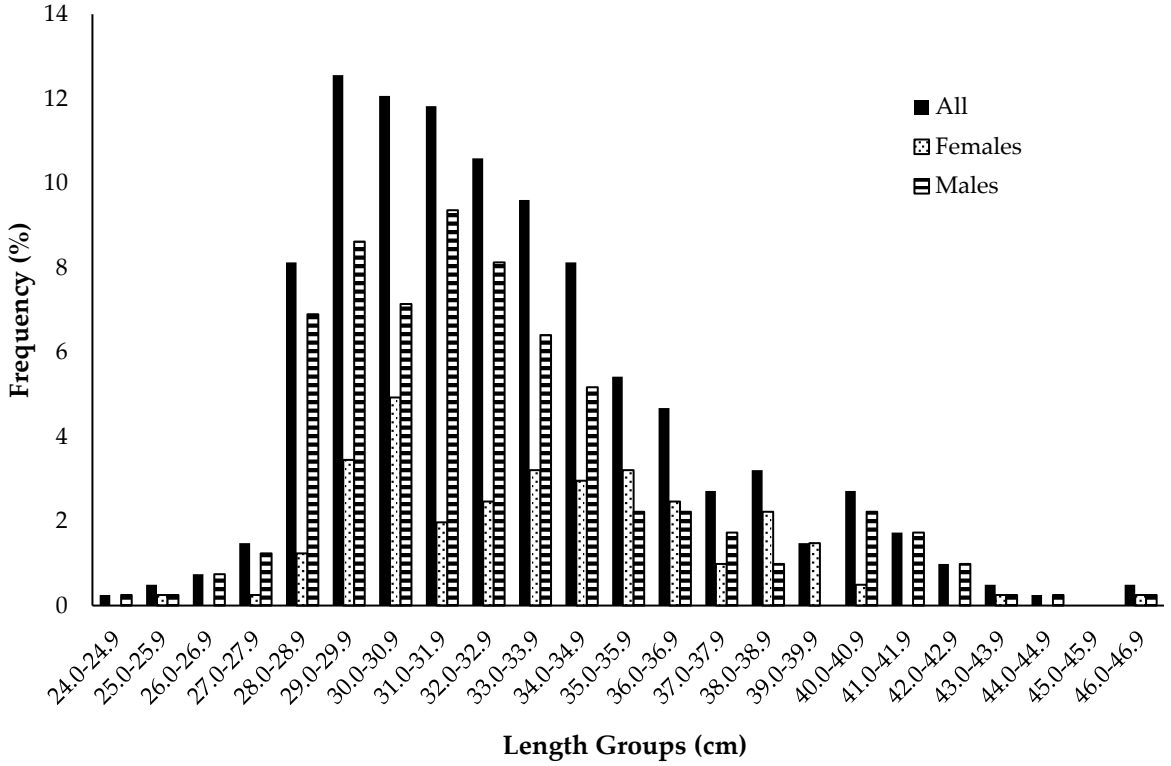

Figure 2. Length frequency of *Cyprinus carpio* acquired from Hasan Uğurlu Reservoir

Table 1. Length-weight relations of common carp (S.E. of b; standard error of b, CI of b; confidence interval of b)

Sex	N	TL_{min}-TL_{max}	W_{min}-W_{max}	a	*b*	S.E. of *b*	CI of *b*	R^2	Growth
All	402	24.9-46.5	226.7-1369.5	0.0163	2.935	0.06	2.862-3.008	0.939	I
Female	130	25.0-46.4	232.5-1103.8	0.0114	2.972	0.11	2.832-3.112	0.932	I
Male	272	24.9-46.5	226.7-1369.5	0.0184	2.898	0.07	2.812-2.984	0.942	I

Table 2. Morphometric relationships between total length (TL), fork length (FL) and standard length (SL) for *Cyprinus carpio* from Hasan Uğurlu Reservoir (N=406)

Equation	a	*b*	95% CI of a	95% CI of b	S.E. of b	R^2
$FL = a + b \times TL$	-1.3937	0.9268	-1.698 to -1.090	0.918 - 0.936	0.005	0.9899
$FL = a + b \times SL$	1.193	1.096	0.858 to 1.528	1.083 - 1.109	0.007	0.9855
$SL = a + b \times TL$	-2.033	0.8357	-2.410 to -1.656	0.824 - 0.847	0.006	0.981
$SL = a + b \times FL$	0.7025	0.8992	-1.016 to -0.389	0.888 - 0.910	0.005	0.9855
$TL = a + b \times FL$	3.0111	1.068	2.600 to 3.422	1.057 - 1.079	0.005	0.9899
$TL = a + b \times SL$	1.821	1.1739	1.511 to 2.131	1.158 - 1.190	0.008	0.981

Growth

Growth coefficient (k), t_0 and L_∞ of all sexes was found as 0.09 $year^{-1}$, -3.02 years and 57.77 cm, respectively (Table 3).

Table 3. Growth parameters of combined, female and male individuals

Sex	k	t_0	L_∞	Φ′
All	0.09	-3.02	57.77	2.48
Female	0.11	-2.63	52.09	2.47
Male	0.05	-4.61	72.31	2.42

Fulton's condition factor

The overall Fulton condition factor (*K*) values for samples ranged from 0.91–1.67 (mean = 1.3). Also, for females and males the K values ranged from 1.06–1.67 and 0.91–1.58, respectively. The Fulton's condition factor varied significantly during the study months ($p < 0.05$), with the peak mean condition value being observed during January (1.36) as shown in Figure 3.

However, there was no significant difference ($p > 0.05$) in the mean condition factor between males (1.30) and females (1.31). The highest (1.36) mean condition for all samples was recorded in size class 29–29.9 and the least (1.20) in size class 31–31.9.

Age

Ages based on actual readings were varied between 3 and 13 years. According to mean lengths of the females and males, it was not detected significant differences. Therefore, the first two ages of mean lengths can be used for both sexes (Table 4).

DISCUSSION

The parameter *a* is the scaling coefficient of the weight of a fish corresponding to its measured length (Kuriakose, 2017). According to previous studies, *a* values varies between 0.00003 and 0.05477. In this study, the *a* parameter was estimated as to be 0.0163. Our estimated *a* value relatively takes place between maximum and minimum values (Table 5).

b value gives information about fish shape and growth type. According to length-weight relationships, considering estimated *b* values, it can be stated that an isometric growth pattern is evident for the specimens. *b* values determined by other authors

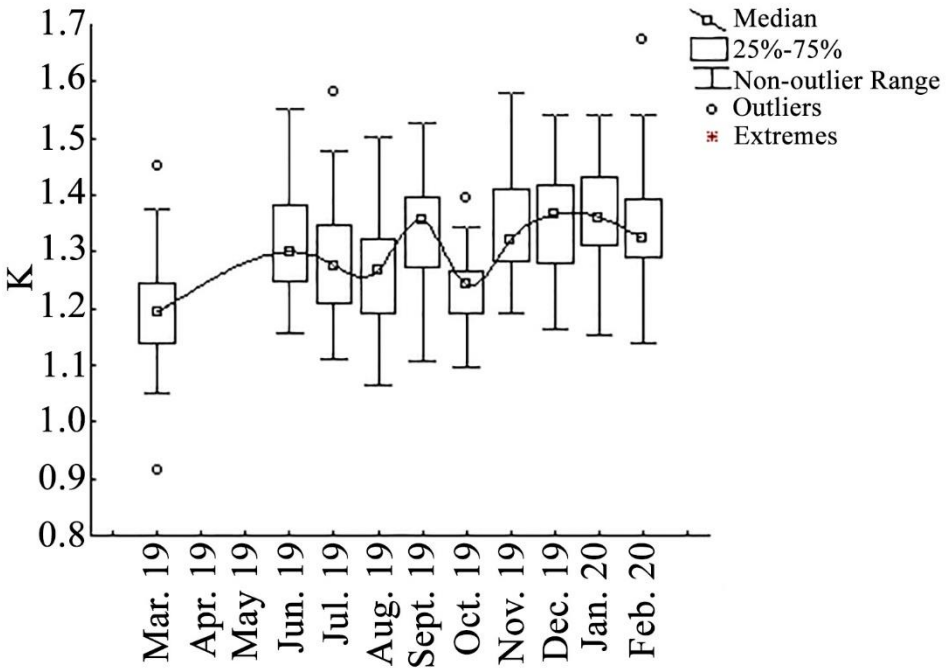

Figure 3. The change of overall mean Fulton's condition factor values by months

Table 4. Age at length of *Cyprinus carpio* samples from fish market, Alaca, Çorum

Sex	Age												
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	13
All	17.1	21.2	25.0±0.1	26.1±0.2	29.0±0.8	31.4±1.1	34.0±0.8	35.8±1.1	38.3±0.8	41.1±0.5	41.6±0.1	42.6±0.9	44.3
Female			25.0	26.0	29.2±0.8	31.3±1.2	34.4±0.9	36.0±1.1	38.6±0.7	39.6±0.1	41.6	42.1±1.5	
Male			24.9	26.1±0.2	29.0±0.8	31.5±1.1	33.8±0.7	35.5±0.9	37.8±0.7	40.6±0.4	41.6±0.1	42.5±0.7	44.3

Table 5. Comparison of *a*, *b*, R^2, t_0, L_∞, k, K, Φ′ and growth type values regarding previous studies and current one

Researcher/s	Location	*a*	*b*	R^2	t_0	L_∞	k	K	Φ′	Growth type
Balık et al. (2006)	Karamık Lake	0.0245	2.952	0.99	-0.245	130	0.075	2.022	7.15	
Karataş et al. (2007)	Almus Dam Lake	0.005	3.319	0.94	-1.922	46.39	0.153	1.34	5.8	+A
Demirkalp (2007a)	Çernek Lake	0.0547	2.665	0.95				1.767		-A
Demirkalp (2007b)	Liman Lake	0.0283	2.871	0.96				1.876		-A
Elp et al. (2008)	Koçköprü Dam Lake	0.04	2.847	0.95	-0.80	84.07	0126	2.471	2.949	
Mert et al. (2008)	Apa Dam Lake	0.000054	2.83	0.93				1.96		
Yilmaz et al. (2010a)	Altınkaya Dam Lake	0.0260	2.825	0.99						-A
Yilmaz et al. (2010a)	Bafra Fish Lakes	0.0298	2.802	0.97						-A
Yilmaz et al. (2010a)	Derbent Dam Lake	0.0210	2.894	0.97						I
Yilmaz et al. (2010a)	Karaboğaz Lake	0.0197	2.895	0.98						I
Yilmaz et al. (2012)	Bafra Fish Lakes	0.0349	2.822	0.98	-0.802	60.96	0.274	1.869	3.00	-A
Macun (2014)	Karaboğaz Lake	0.00003	2.88	0.96				1.78		-A
Saylar & Benzer (2014)	Mogan Lake	0.00006	2.87	0.93	-1.74	49.6	0.24	1.984		
Birecikligil et al. (2016)	Nevşehir - Kızılırmak	0.001	3.138	0.93				1.52		+A
Buhan et al. (2016)	Almus Dam Lake	0.0138	3.018	0.99						I
Present study	Hasan Uğurlu Reservoir	0.0163	2.935	0.94	-4.61	72.31	0.09	1.3	2.42	I

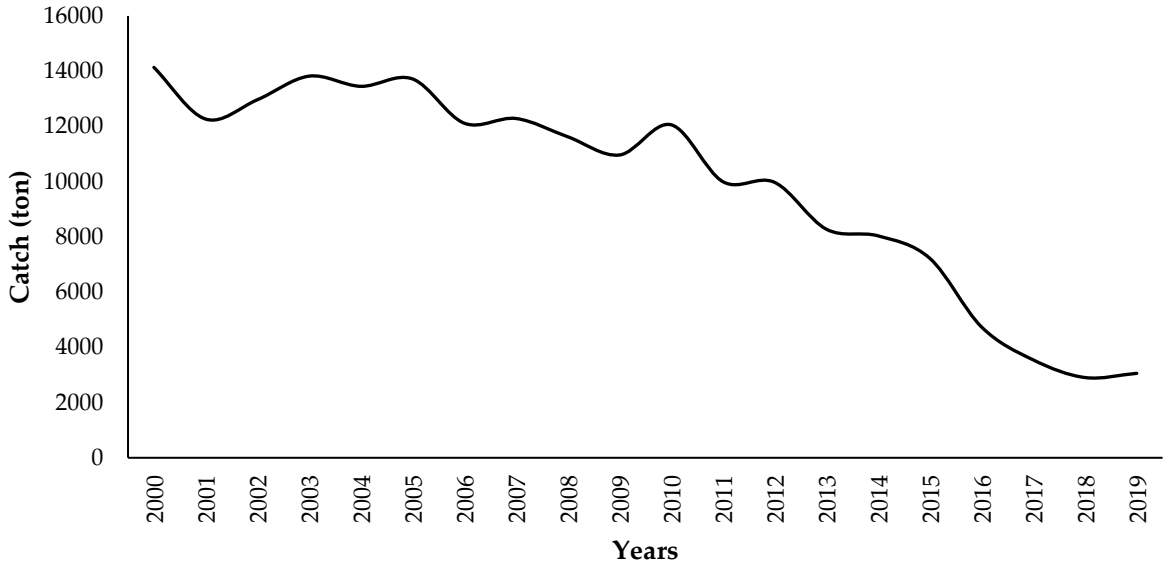

Figure 4. Common carp catch of Türkiye by years (TUIK, 2021)

(Balık et al., 2006; Mert et al., 2008; Yilmaz et al., 2010a, 2012), are also in accordance with the findings of the current study. *b* values of the studies range between 2.83 to 3.31. As found in the most of the previous studies that *C. carpio* shows isometric and negative allometric growth. However, two studies, Birecikligil et al. (2016) and present study, show positive allometric growth (Table 5). These variations may be associated with some biotic and abiotic effects such as latitude, altitude, temperature, food abundance, population density.

As it is known, the exponential regression is used to determine the length-weight relationships. In this estimation, R^2 shows the model accuracy and more close R^2 to 1 means more accurate the model becomes. All R^2 values of the previous studies are very close to 1. Our R^2 value was estimated as 0.94 and this value is acceptable for exponential model accuracy (Table 5).

Vilizzi et al. (2014b) calculated the average growth coefficient (k) of the *C. carpio* species found in Anatolia as 0.135 $year^{-1}$. The k values in the present study were found as 0.09 $years^{-1}$, 0.11 $years^{-1}$ and 0.05 $years^{-1}$ for females, males and all individuals, respectively. The calculated values are close to the averages of the studies conducted in Anatolia. The t_0 values in the current study were found higher than the values calculated for Anatolia. This difference may be attributed to the calculation methods applied for t_0 (Table 5).

The relatively low growth coefficient for the *C. carpio* species is an indicator that this species reached larger sizes later on. Also it can be seen in Table 6, captured common carp reach high ages. Denney et al. (2002) reported that large, slow-growing stocks and species had significantly low rates of stock participation. They also revealed that maturation at older ages has a significant relationship with low stock participation. On the other hand, the studies on the first reproductive age of *C. carpio* species are examined, it was observed that the common carp reproduce between the ages of 2 and 5 (Vilizzi et al., 2014b). In this context, many factors such as water temperature, latitude differences, nutrition of the study regions may have affected the growth and first reproductive age (Wotton, 2012). Considering that the carp individuals used in the present study have slow growth. According to the literature (Vilizzi et al., 2014b), 5-year-old individuals reached their first reproduction length (29.0 cm). Captured individuals were below the first reproduction length represent 11.8% in total. This ratio was thought be low and the length prohibition in the fishery communique serves for common carp stock sustainability.

Fulton's condition values were found between 1.34 and 2.47 in studies on common carp in Türkiye (Table 5). Also the present result of study, 1.3, is quite close to values of the previous studies.

C. carpio is an important species for Turkish inland fishery. Although there are regions where they are naturally found, this species is released to some regions by the state for restocking. However, due to the small size of the released individuals, morphological similarities with some other invasive species (such as *Carassius gibelio*), inappropriate stocking strategies, and limited breeding areas, it can be stated that the release does not reach its goal completely (Gaygusuz et al., 2015). This situation may be supported by annual common carp catch in Türkiye (TUIK, 2021).

Considering the common carp catch by years, a significant decrease can be observed (Figure 4). This decrease could be attributed to harvesting in gonadal development times of common carp. According to Turkish fishery communique, common carp has various seasonal closures throughout the Türkiye. However, factors such as nutritional conditions and altitude variations originating from regional differences, can affects its reproduction and stock recruitment relationships. Therefore, seasonal closures should be reconsidered, and climate change and regional differences should be taken into account to determine seasonal closures.

On the other hand, in the meaning ecological perspective, considering the recommendations made by Flajshans & Hulata (2007), the importance of keeping common carp populations under control becomes apparent. As common carp is an important angling species in many countries, precautions should be taken to prevent its release into new water bodies and stocking for recreational aims should be restricted to closed bodies of water.

CONCLUSION

In conclusion, common carp is commercially important for local fishermen in many freshwater bodies in Türkiye. Therefore, proper management strategies should be applied for sustaining common carp stocks in the direction of biological data.

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Compliance with Ethical Standards

Authors' Contributions

ÖY: Manuscript preparation, edit

HC: Manuscript preparation, draft, visualisation

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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